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DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Maryland 20084

BIBLIOGRAPHY ON FOULING, BIODETERIORATION AND THEIR CONTROL

by

Anne M. Becka
Vincent J. Castelli
Eugene C. Fischer

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SHIP MATERIALS ENGINEERING DEPARTMENT
RESEARCH AND DEVELOPMENT REPORT

June 1981

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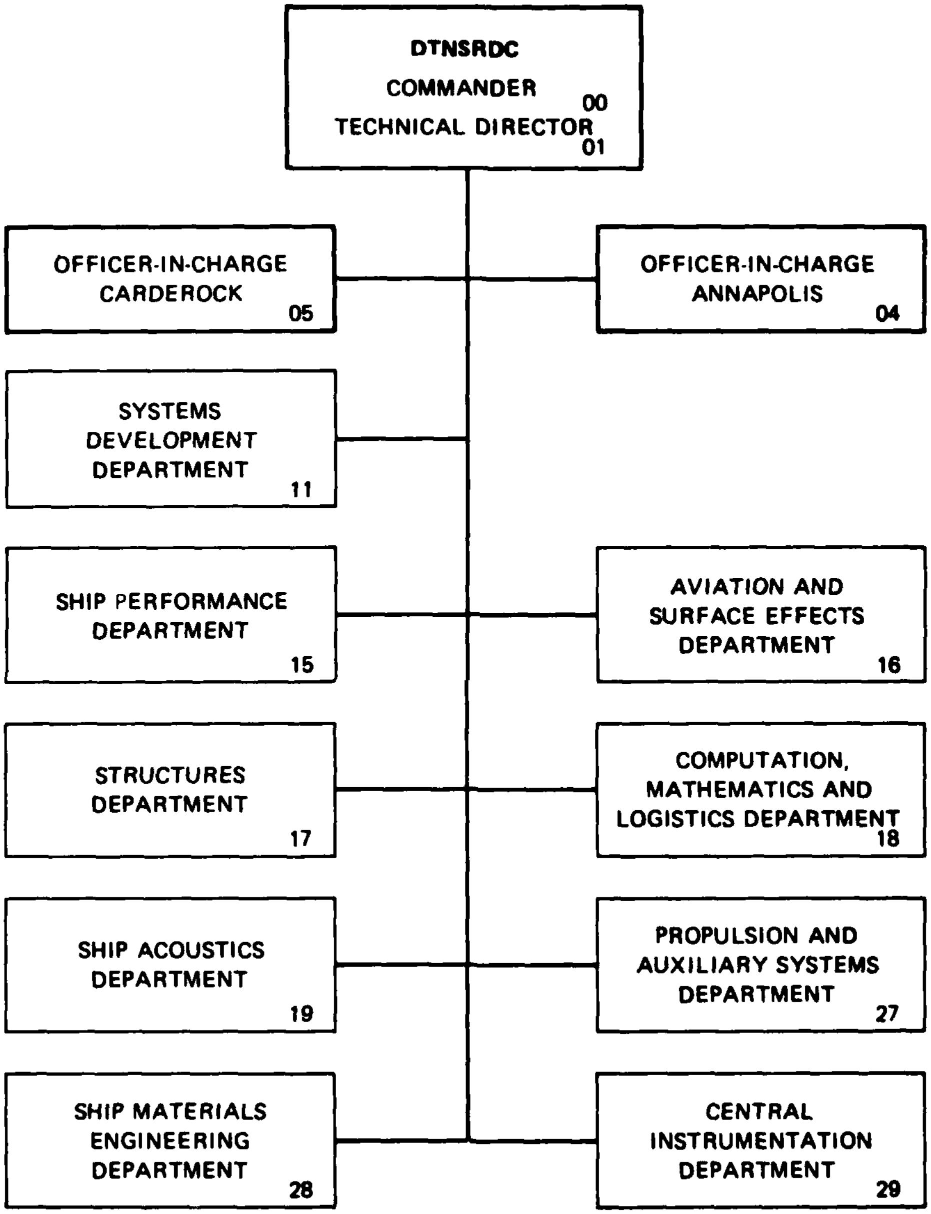

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report is a compilation of a bibliography on "Fouling Control Technology." It presents over 500 references applicable to 40 areas under the broad topic of fouling control. It is provided through a DTNSRDC computerized fouling control data base which is intended to be updated on an annual basis.

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ABSTRACT

This report is a compilation of a bibliography on "Fouling Control Technology." It presents over 500 references applicable to 40 areas under the broad topic of Fouling Control. It is provided through a David Taylor Naval Ship Research and Development Center computerized fouling control data base which is intended to be updated on an annual basis.

GENERAL INTRODUCTION

Several researchers at the David Taylor Naval Ship Research and Development Center (DTNSRDC) were requested to prepare a review paper on "Fouling Control Technology." Preliminary preparations produced an outline of 40 topics and subtopics (Table 1) to potentially be covered in this paper. An on-line library literature search revealed 20,000 citations under these topics and more careful review produced over 8,000 articles to be obtained.

An efficient, computerized method was developed to maintain a listing of the articles and determine which articles were applicable to any one section. As of this writing, over 500 articles are maintained on the data base with additions being made on a routine basis.

Upon receipt of a copy of an article, one of the researchers would review it for content and decision on its retention in the bibiographic file. Forms were provided which assigned the article a unique file number and also identified bibliographic and applicable section information. Computerizing the information on these forms provided a data base which can be accessed in a wide variety of methods.

Table 1
Outline of Topics and Subtopics

1.0	INTRODUCTION
1.1	Designing Integrated Fouling Control System
2.0	EVALUATION OF EFFICACY
2.1	In Situ Tsting
2.1.1	Raft Tests
2.2	Accelerated Tests
2.2.1	Dynamic
2.2.2	Bioassay
2.2.3	Leaching Rate
3.0	CHEMICAL CONTROL TECHNOLOGY
3.1	Toxic Control Agents
3.1.1	Delivery Systems
3.1.1.1	Coatings
3.1.1.3	Direct Injection
3.1.1.4	Impregnation
3.1.1.5	Structural Incorporation
3.2	Non-Toxic Control Agents
3.2.1	Delivery Systems
4.0	PHYSICAL CONTROL TECHNOLOGY
4.1	Mechanical Methods of Control
4.1.1	Scrubbing
4.1.1.1	Exterior
4.1.1.2	Interior
4.12	Jets
4.1.3	Ultrasonics
4.1.4	Low Surface Energy Materials
4.2	Electrical Methods
4.3	Magnetic Methods
4.4	Optical Methods
4.5	Nuclear Methods
4.7	Osmotic Methods
4.8	Surface Modification Methods
4.9	Explosive Removal Methods
5.0	CONCLUSIONS
5.1	Present Practice
5.2	Future Directions

The "Fouling Control Technology" paper is complete, but the data base is such a useful research tool that it is to be maintained indefinitely. This report is a compilation of the data base. Each section of the original report will be contained herein with a list of the references identified for that topic. Additionally, the full bibliography from the original report is listed at the end of this centralized compilation of literature in the area of fouling control.

INTRODUCTION

Articles referenced under introduction are those which were useful in identifying the development, and the state-of-the-art of the field of fouling control technology. These articles will also help define the nature of marine fouling.

REFERENCES

4, 6, 7, 16, 20, 23, 43, 44, 53, 56, 58, 61, 68, 69, 72, 73, 74, 75, 86, 87, 92, 93, 96, 103, 105, 109, 111, 112, 113, 115, 116, 121, 127, 130, 131, 132, 134, 135, 136, 145, 149, 153, 154, 162, 168, 175, 193, 194, 199, 200, 202, 203, 204, 205, 206, 207, 213, 216, 217, 222, 224, 229, 240, 241, 242, 244, 246, 247, 248, 250, 252, 253, 254, 255, 257, 259, 260, 262, 264, 266, 267, 270, 284, 285, 286, 293, 296, 301, 303, 306, 311, 330, 333, 334, 339, 340, 346, 349, 352, 355, 357, 360, 365, 368, 372, 376, 386, 398, 402, 411, 413, 415, 423, 424, 426, 440, 442, 452, 457, 462, 465, 472, 475, 479, 481, 482, 489, 499, 502, 505, 506, 512, 513, 516, 520, 534, 536, 543

DESIGNING INTEGRATED FOULING CONTROL SYSTEMS

Efficient control of fouling is generally the result of careful design and usually involves not just the use of one control method, such as AF paints, but rather the linking one or more methods, such as AF paint, and scrubbing together with additional design and maintenance approaches. The philosophy behind integrated fouling control systems is examined in these citations.

REFERENCES
17, 25, 53, 58, 64, 65, 68, 69, 72, 85, 86, 87, 92, 93, 96, 103, 109, 115, 121, 123, 126, 130, 136, 142, 145, 154, 157, 164, 166, 173, 175, 193, 199, 204, 206, 216, 222, 228, 247, 260, 267, 270, 279, 281, 285, 301, 311, 327, 332, 333, 340, 341, 349, 365, 382, 405, 419, 420, 428, 431, 457, 468, 470, 472, 474, 481, 482, 484, 499, 504, 516, 525, 526

EVALUATION OF EFFICACY

These articles examine various methods of determining the efficacy and efficiency of a fouling control system.

REFERENCES
3, 4, 5, 13, 14, 18, 19, 25, 34, 35, 39, 57, 58, 59, 66, 67, 68, 72, 77, 79, 80, 87, 92, 94, 102, 104, 128, 143,144, 146, 150, 155, 161, 162, 163, 164, 167, 187, 188, 189, 192, 210, 211, 218, 219, 220, 222, 234, 235, 240, 247, 248, 252, 253, 263, 274, 275, 287, 293, 300, 316, 326, 336, 340, 341, 343, 347, 350, 351, 354, 366, 371, 372, 373, 374, 378, 379, 380, 388, 391, 418, 419, 421, 431, 433, 442, 448, 449, 453, 454, 455, 457, 476, 477, 480, 481, 484, 486, 498, 504, 522, 527, 538, 546

IN SITU TESTING

Various methods of testing have been developed to examine the efficiency of a fouling control system in an actual marine environment, either under actual or simulated service conditions.

REFERENCES
3, 4, 5, 6, 13, 14, 18, 39, 57, 58, 59, 67, 68, 79, 80, 87, 94, 128, 143, 144, 145, 146, 161, 162, 164, 187, 189, 192, 211, 218, 219, 220, 233, 234, 238, 247, 248, 259, 293, 295, 298, 326, 340, 343, 349, 350, 354, 378, 379, 380, 387, 388, 390, 391, 418, 419, 421, 431, 433, 449, 454, 498, 522, 538

RAFT TESTING

Raft tests are a method by which samples of an antifouling material, such as an antifouling coating, can be exposed to a marine environment.

REFERENCES
3, 14, 34, 58, 110, 144, 145, 146, 162, 163, 231, 232, 234, 238 259, 293, 298, 342, 379, 418, 454, 497, 514, 528

ACCELERATED TESTING

Certain performance characteristics can be estimated by tests conducted under accelerated conditions. These tests can be indicative of long-term material performance.

REFERENCES
3, 35, 66, 77, 104, 117, 144, 145, 146,150, 155, 163, 187, 189, 210, 211, 227, 235, 236, 238, 246, 263, 280, 287, 293, 308, 313, 316, 343, 347, 351, 370, 380, 385, 418, 441, 455, 476, 480, 527, 546

DYNAMIC TESTING

Dynamic tests include those tests on which the material to be characterized is placed in an environment with relative motion between the substrate and the seawater. An example of this is the rotating drum test used for determining antifouling paint performance.

REFERENCES
104, 146, 163, 187, 189, 343, 454

BIOASSAY

A bioassay of a material would involve exposing the material to living organisms under a controlled environment and determining some response parameter, such as toxicity, to the target organisms.

REFERENCES
6, 53, 66, 105, 139, 198, 209, 210, 211, 218, 219, 220, 240, 243, 244, 259, 263, 273, 287, 293, 295, 308, 351, 380, 418, 422, 427, 441, 453, 455, 456, 458, 476, 517, 527, 528, 541

LEACHING RATE

A leaching rate test is used to determine how quickly the toxic moiety of antifouling material is released into the environment. This can be helpful in predicting the expected lifetime of an antifouling material.

REFERENCES
35, 77, 117, 120, 129, 143, 144, 145, 150, 155, 189, 218, 219, 220, 233, 235, 236, 293, 296, 313, 314, 316, 317, 347, 351, 371, 373, 374, 457, 505, 528

CHEMICAL CONTROL TECHNOLOGY

One area of major emphasis in fouling control has been the incorporation of a chemical into a material which, when released, prevents the accumulation of fouling. Extensive research has been done into the most effective chemicals to be used and the most efficient delivery systems to be used with them to provide long-term antifouling protection.

REFERENCES

2, 4, 5, 7, 9, 10, 11, 13, 18, 21, 26, 28, 29, 31, 33, 35, 37, 39 40, 42, 43, 44, 47, 48, 50, 51, 53, 57, 58, 59, 62, 63, 64, 65, 67, 68, 70, 71, 78, 79, 80, 81, 82, 88, 89, 90, 91, 92, 93, 94, 97, 98, 99, 102, 103, 104, 106, 107, 108, 109, 116, 117, 122, 128, 133, 135, 138, 139, 141, 142, 143, 144, 148, 150, 151, 152, 160, 161, 162, 164, 166, 167, 169, 171, 174, 175, 176, 177, 178, 179, 180, 182, 183, 187, 188, 189, 190, 191, 192, 195, 196, 198, 199, 200, 201, 205, 207, 208, 209, 217, 218, 220, 221, 226, 228, 232, 236, 237, 239, 242, 244, 249, 251, 252, 253, 258, 259, 265, 268, 269, 270, 276, 277, 279, 280, 282, 285, 287, 289, 291, 294, 302, 303, 307, 309, 313, 314, 316, 317, 320, 321, 323, 324, 325, 326, 327, 328, 334, 336, 338, 340, 341, 344, 345, 348, 353, 354, 358, 361, 364, 365, 366, 368, 371, 372, 373, 374, 378, 379, 380, 381, 382, 383, 386, 388, 391, 394, 397, 399, 405, 406, 407, 408, 409, 412, 413, 414, 416, 419, 420, 421, 422, 424, 426, 427, 430, 431, 432, 434, 435, 437, 438, 440, 443, 444, 445, 446, 449, 450, 451, 453, 455, 456, 457, 458, 459, 463, 466, 468, 469, 470, 471, 473, 478, 480, 482, 484, 485, 486, 491, 492, 493, 494, 496, 501, 503, 504, 508, 511, 514, 519, 521, 522, 524, 525, 530, 531, 533, 535, 538, 541, 542, 545, 547

TOXIC CONTROL AGENTS

A wide array of pesticidal products have been examined for use in marine fouling control.

REFERENCES

2, 4, 5, 9, 10, 13, 18, 21, 29, 31, 33, 35, 37, 39, 40, 42, 43, 47, 48, 50, 51, 53, 57, 58, 59, 61, 62, 63, 64, 65, 67, 68, 71, 78, 80, 81, 82, 88, 89, 90, 91, 92, 93, 94, 97, 98, 99, 102, 104, 117, 122, 128, 129, 133, 138, 141, 142, 143, 144, 148, 150, 151, 152, 160, 161, 162, 164, 166, 167, 169, 171, 174, 175, 176, 178, 179, 180, 182, 183, 187, 188, 189, 190, 191, 192, 195, 196, 197, 198, 200, 201, 205, 207, 208, 209, 210, 217, 218, 220, 221, 226, 228, 232, 236, 239, 244, 249, 251, 258, 259, 265, 268, 269, 270, 271, 276, 277, 280, 282, 285, 289, 291, 292, 297, 302, 307, 309, 311, 312, 313, 315, 316, 320, 321, 323, 324, 325, 327, 328, 334, 340, 341, 344, 345, 348, 353, 354, 358, 361, 368, 371, 375, 378, 379, 380, 381, 382, 383, 385, 390, 391, 394, 395, 397, 405, 406, 407, 408, 409, 413, 414, 416, 419, 420, 421, 422, 424, 426, 430, 431, 432, 433, 434, 437, 438, 440, 443, 444, 445, 446, 449, 450, 451, 453, 455, 456, 457, 458, 459, 463, 466, 468, 471, 473, 478, 482, 484, 485, 486, 487, 492, 493, 494, 496, 501, 503, 504, 508, 511, 514, 517, 519, 521, 524, 525, 526, 530, 531, 533, 538, 541, 542, 545, 547

DELIVERY SYSTEMS (TOXIC)

Determining a toxic compound to be used is only a small part of fouling contol. A major step is development of a method to provide an adequate dosage of the toxic agent in intimate contact with the surface to be protected.

REFERENCES

2, 4, 9, 10, 21, 22, 29, 31, 33, 37, 42, 43, 47, 48, 50, 51, 53, 54, 58, 62, 63, 64, 65, 67, 68, 71, 78, 82, 90, 91, 92, 93, 94, 96, 97, 98, 99, 102, 117, 120, 128, 129, 133, 138, 143, 144, 148, 151, 152, 160, 162, 164, 166, 167, 169, 174, 175, 176, 178, 179, 182, 183, 189, 190, 192, 195, 196, 197, 198, 201, 207, 208, 221, 228, 232, 233, 236, 249, 258, 265, 268, 269, 270, 273, 276, 277, 281, 285, 289, 291, 302, 309, 311, 312, 313, 316, 320, 321, 324, 327, 328, 334, 340, 341, 345, 348, 353, 362, 365, 368, 379, 380, 381, 383, 386, 395, 400, 407, 408, 409, 413, 414, 416, 419, 420, 422, 426, 430, 432, 433, 435, 438, 440, 443, 445, 450, 451, 459, 463, 464, 466, 468, 470, 473, 474, 478, 482, 484, 485, 487, 492, 493, 494, 496, 501, 503, 511, 519, 521, 525, 526, 531, 533, 545, 547

547 COATINGS

The major method of protecting external surfaces has been to cover the surface with a coating containing a toxic agent. Various methods of incorporating the toxic agent into the coating have resulted in varying fouling-free lifespans. Recent developments have been to incorporate the toxic agents into the polymeric resin base of the coating, resulting in low leaching rates and long-term antifouling protection.

REFERENCES

2, 9, 10, 11, 13, 19, 20, 21, 23, 24, 31, 37, 42, 48, 50, 51, 53, 54, 57, 58, 59, 62, 63, 64, 71, 74, 80, 82, 89, 90, 92, 93, 94, 96, 97, 98, 99, 105, 117, 143, 144, 150, 151, 160, 162, 163, 164, 165, 166, 167, 174, 175, 176, 177, 178, 179, 180, 183, 187, 188, 189, 192, 193, 195, 196, 198, 202, 207, 208, 216, 217, 226, 227, 231, 232, 233, 234, 236, 237, 239, 243, 244, 260, 265, 269, 273, 280, 283, 285, 289, 291, 292, 311, 312, 313, 314, 316, 317, 319, 326, 332, 334, 338, 340, 344, 345, 346, 348, 354, 365, 368, 369, 371, 373, 374, 375, 377, 380, 383, 388, 403, 405, 406, 408, 410, 412, 413, 419, 420, 421, 422, 426, 430, 431, 432, 433, 434, 435, 454, 455, 459, 463, 464, 466, 475, 478, 485, 486, 487, 493, 494, 496, 502, 503, 504, 514, 515, 522, 533, 536, 538, 545

ELASTOMERS

A variety of work has been done on the incorporation of toxic agents into elastomeric (rubber) materials. These materials have been useful in a wide variety of specialized marine applications.

REFERENCES

56, 92, 93, 96, 145, 147, 148, 162, 164, 191, 207, 223, 281, 311, 312, 319, 337, 365, 369, 407, 419, 422, 487, 503, 538

DIRECT INJECTION

The direct injection or generation of biocidal agents, such as chlorine, into areas such as piping systems has proved highly useful in the prevention of fouling.

REFERENCES

5, 10, 18, 29, 39, 40, 47, 49, 65, 67, 68, 78, 83, 88, 96, 103, 104, 128, 130, 133, 141, 142, 159, 166, 169, 190, 200, 201, 207, 217, 249, 251, 258, 261, 268, 282, 289, 302, 320, 321, 324, 327,
328, 334, 340, 341, 353, 365, 3[illegible], 397, 416, 443, 444, 445, 446,
328, 334, 340, 341, 353, 365, 381, 397, 416, 443, 444, 445, 446,
448, 453, 468, 470, 471, 473, 480, 484, 492, 503, 507, 511, 521, 525, 526, 531, 547

IMPREGNATION

The protection of wood piers and bulkheads has presented a major problem in biocontrol. The incorporation of toxic agents into wood is vital in maintaining these facilities at reasonable performance and cost levels.

REFRENCES

28, 43, 70, 79, 81, 92, 96, 122, 138, 151, 171, 182, 197, 207, 217, 225, 226, 270, 274, 275, 276, 277, 278, 292, 309, 342, 365, 390, 408, 413, 439, 441, 442, 448, 449, 450, 451, 495, 503, 508

STRUCTURAL INCORPORATION

The incorporation of a toxic agent into actual materials of construction is advantageous from maintenance standpoints. Alloys of copper and fouling resistant structural composites are the most prominent areas in this technology.

REFERENCES

4, 33, 73, 92, 93, 96, 102, 151, 187, 192, 197, 207, 226, 289, 309, 334, 345, 354, 365, 378, 379, 409, 438, 440, 480, 501, 519

NON-TOXIC CONTROL AGENTS

Due to concerns over environmental and worker safety, it is advantageous to investigate non-toxic chemical agents, such as hormones and repellents, to prevent the accumulation of fouling.

REFERENCES

7, 23, 26, 32, 43, 53, 76, 79, 80, 105, 106, 107, 134, 135, 172, 202, 208, 242, 244, 258, 285, 297, 299, 303, 310, 329, 330, 332, 334, 340, 359, 364, 365, 366, 377, 389, 394, 446, 462, 465, 468, 483, 515, 535

DELIVERY SYSTEMS (NON-TOXIC)

Just as it was necessary to have a system to deliver toxic agents, it is also necessary to develop methods to deliver non-toxic agents to the surface to make these approaches practical.

REFERENCES

43, 53, 107, 207, 208, 258, 285, 297, 310, 334, 365, 412, 446, 535

PHYSICAL CONTROL TECHNOLOGY

Various methods have been developed to physically prevent or remove fouling. Some methods involve the use of various forms of energy, modification of the surface or the use of mechanical devices to remove or prevent fouling.

REFERENCES

1, 12, 15, 19, 25, 27, 30, 36, 41, 43, 44, 55, 60, 68, 72, 79, 92, 93, 95, 100, 101, 112, 124, 136, 140, 156, 157, 158, 159, 166, 170, 204, 207, 212, 215, 222, 230, 245, 252, 253, 258, 285, 289, 290, 300, 304, 305, 318, 322, 327, 334, 335, 339, 340, 341, 365, 376, 384, 389, 392, 393, 396, 397, 401, 404, 416, 417, 425, 428, 429, 436, 447, 460, 467, 468, 473, 481, 488, 500, 509, 510, 516, 523, 529, 531, 537, 539, 540

MECHANICAL METHODS OF CONTROL

The oldest means, and still one of the current commercial approaches, relies upon brute force to dislodge fouling organisms.

REFERENCES

12, 27, 55, 72, 92, 93, 95, 127, 157, 170, 204, 215, 217, 222, 241, 245, 258, 300, 318, 322, 327, 334, 338, 339, 340, 367, 365, 389, 392, 404, 415, 428, 429, 467, 468, 481, 482, 500, 509, 510, 516, 529

SCRUBBING

Scrubbing removes accumulated fouling. This is an effective method by which fouling is prevented or removed.

REFERENCES
19, 27, 53, 72, 92, 93, 95, 125, 204, 215, 217, 222, 245, 258, 300, 318, 327, 334, 338, 363, 365, 404, 415, 428, 429, 467, 468, 481, 509, 510, 516, 529

EXTERIOR SCRUBBING

These references cover those methods by which fouling is removed from exterior surfaces, such as ship hulls.

REFERENCES
92, 93, 170, 217, 365, 428, 429, 509, 510, 516

INTERIOR SCRUBBING

This section involves those methods by which fouling is removed from interior surfaces, such as heat exchangers and other piping systems.

REFERENCES
72, 95, 204, 222, 258, 300, 318, 327, 365, 404, 467, 468, 481, 516

JETS

These references cover those methods by which a moving stream is directed towards the surface from which the fouling is to be removed.

REFERENCES

12, 92, 93, 125, 127, 170, 217, 258, 288, 353, 365, 428, 516

ULTRASONICS

The use of ultrasonic energy applied to or on an irradiated surface has been demonstrated as an effective fouling control method for ships and other structures.

REFERENCES

25, 30, 36, 53, 55, 118, 249, 258, 285, 289, 353, 365, 392, 468, 482, 516, 537

LOW SURFACE ENERGY MATERIALS

The use of low surface energy materials will not prevent the attachment of fouling organisms, but will allow their easy removal once they are attached.

REFERENCES

41, 68, 157, 158, 285, 353, 365, 398, 468, 482, 516

ELECTRICAL METHODS

Electrical currents and fields are generally regarded as antagonists of growth in biological systems.

REFERENCES

53, 100, 140, 159, 212, 285, 289, 393, 396, 417, 436, 447, 468, 473, 516

MAGNETIC METHODS

Attempts have been made to identify and quantify magnetic responses in bio-organisms.

REFERENCES

60, 230, 290, 304, 305, 335, 353, 516

OPTICAL METHODS

The use of ultraviolet and high intensity light for the prevention and removal of fouling can be of aid in certain systems.

REFERENCES

53, 258, 322, 365, 468, 490, 516

NUCLEAR METHODS

Ionizing radiation is known to be injurious to all living systems at sufficiently large doses. Recent efforts have been underway to revive this approach.

REFERENCES

1, 15, 53, 384, 468, 516, 534, 539, 540

THERMAL METHODS

Sufficient heat will discourage biological attachment in the initial stages and kill fouling organisms previously attached.

REFERENCES

16, 53, 68, 84, 101, 119, 166, 214, 248, 282, 340, 341, 376, 416, 452, 468, 488, 516, 531, 537

OSMOTIC METHODS

Most common marine fouling organisms will not tolerate significant changes in the salinity of the medium, particularly in the extreme of fresh water.

REFERENCES

53, 119, 166, 258, 282, 285, 340, 401, 425, 439, 460, 516

SURFACE MODIFICATION METHOD

Many fouling organisms respond to the surface condition of the substrate to which they attach. This an have an influence on the normal rates of fouling.

REFERENCES

32, 41, 45, 46, 53, 68, 76, 112, 137, 156, 157, 158, 202, 285, 296, 306, 353, 356, 365, 377, 397, 410, 468, 482, 516, 535

EXPLOSIVE REMOVAL METHODS

Shock waves, generated by the detonation of an explosive device, are a sure way of dislodging even the most tenaciously attached fouling organism.

REFERENCE

516

CONCLUSIONS

Several authors have evaluated the wide range of potential antifouling control technology for a host of specialized applications, with the full knowledge that there is no "one best" solution.

REFERENCES

7, 53, 86, 92, 93, 95, 114, 115, 127, 146, 157, 162, 164, 175, 199, 204, 301, 327, 339, 372, 454, 479, 481

PRESENT PRACTICE

The state-of-the-art in fouling control as presently practiced varies, depending upon the nature of the problem, location, size, accessibility, and a host of other variables.

REFERENCES

11, 19, 44, 53, 65, 68, 72, 79, 85, 86, 92, 93, 95, 114, 115, 121, 122, 124, 133, 161, 175, 176, 194, 199, 201, 204, 207, 222, 246, 247, 258, 266, 301, 311, 327, 339, 341, 365, 372, 386, 404, 411, 449, 454, 468, 475, 481, 492, 499, 500, 513

FUTURE DIRECTIONS

A significant amount of research in fouling control is currently underway, but there is still much to be done.

REFERENCES

7, 16, 19, 20, 32, 41, 44, 53, 61, 72, 85, 86, 92, 93, 95, 96, 103, 105, 109, 113, 114, 115, 121, 123, 127, 130, 146, 150, 164, 175, 199, 207, 208, 209, 222, 242, 246, 258, 260, 285, 296, 301, 311, 317, 327, 339, 355, 365, 367, 372, 419, 424, 426, 466, 468, 469, 472, 479, 499, 516, 518, 528, 535

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LIST OF ABBREVIATIONS

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-A-

Adv Org Coat Sci Tech - Advances in Organic Coatings Science and Technology

Amer Zool - American Zoology

Am Pap Ind - American Paper Industry

Anal Chem - Analytical Chemistry

Anti-Corros - Anti-Corrosion

Anti-Corros Meth Mats - Anti-Corrosion Methods and Materials

Appl Environ Microl - Applied Environmental Microbiology

Apply Microbiol - Applied Microbioloy

Arch Environ Cont - Archives of Environmental Contamination and Toxicology

Arch Environ Contam Toxicol - Archives of Environmental Contamination and Toxicology

Arch Soc Zoo Bot Fenn - Archivium Societatis Zoological Botanical Fennical "Vanamo"

ASTM - American Society of Testing Materials

Aust - Australian

Aust J. Sci - Australian Journal of Science

-B-

Biol Bull - Biological Bulletin

Biol Bull Mar Biol Lab, Woods Hole - Biological Bulletin of the Marine Biological Laboratory at Woods Hole, MA

Bull Environ Cont Toxic - Bulletin of Environmental Contamination and Toxicology

Bull Mar Sci - Bulletin of Marine Science

-C-

Cal Fish Game - California Fish and Game

Can Fish Resch Board - Canadian Fisheries Research Board

Can J. Chem Engng - Canadian Journal of Chemical Engineering

Can J. Microbiol - Canadian Journal of Microbiology

Can Paint Finish - Canadian Paint and Finishing

Can Shipp Mar Engng - Canadian Shipping and Marine Engineering

Chem Engng - Chemical Engineering

Chem Weekly - Chemistry Weekly

Chemy Ind - Chemistry and Industry

Chesapeake Sci - Chesapeake Science

Coat Plas Prep - Coatings and Plastics Preprints

Comp Biochem Physiol - Comparative Biochemistry and Physiology

Corros Mar Foul - Corrosion and Marine Fouling

Corros Prev - Corrosion Prevention

Corros Prev Control - Corrosion Prevention and Control

-D-

Dev Ind Microb - Developments in Industrial Microbiology

DOC/MARAD - U. S. Department of Commerce, Maritime Administration

DOD Mat Res Lab, Aust - Department of Defense, Material Research Laboratory, Australia

DOE - U. S. Department of Energy

DTNSRDC - David Taylor Naval Ship Research and Development Center

DOT/USCG - U. S. Department of Transportation - U. S. Coast Guard

-E-

Effluent Wat Treat - Effluent and Water Treatment
Electl Engng - Electrical Engineering
Environ Hlth Perspect - Environmental Health Perspectives
Environ Resch - Environmental Research
Environ Sci Technol - Environmental Science and Technoloy
EPA - U. S. Environmental Protection Agency
EPRI - Electric Power Research Institute
Europ Poly J - European Polymer Journal

-F-

Finish Ind - Finishing Industry
Foreign Sci Bull - Foreign Science Bulletin

-G-

Ga Acad Sci Bull - Georgia Academy of Sciences Bulletin

-H-

Hlth Phys - Health Physics
Hydrocarb Process - Hydrocarbon Processing

-I-

Ind Eng Chem Prod Res Dev - Industrial Engineering Chemical Products Research and Development
Ind Engng Chem - Industrial Engineering Chemistry
Indian J. Exp Biol - Indian Journal of Experimental Biology
Ind J. Technol - Indian Journal of Technology
Ind Acad Wood Science - Indian Academy of Wood Science
Intl Biodet Bull - International Biodeterioration Bulletin
Intl Petrol Times - International Petroleum Times

-J-

J Acoust Soc Am - Journal of the Acoustical Society of America

J Agric Fd Chem - Journal of Agriculture and Food Chemistry

J Am Dent Asc - Journal of the American Dental Association

J Am Soc Nav Engrs - Journal of the American Society of Naval Engineers

J Am Wat Wks Asc - Journal of the American Water Works Association

J Anim Ecol - Journal of Animal Ecology

J Appl Chem Biotechnol - Journal of Applied Chemistry and Biotechnology

J Appl Ecol - Journal of Applied Ecology

J Appl Polm Sci - Journal of Applied Polymer Science

J Aquat Plt Manage - Journal of Aquatic Plant Management

J Bombay Nat Hist Soc - Journal of the Bombay Natural Historical Society

J Chem U. A. R. - Journal of Chemistry, United Arab Republic

J Coatings Technol - Journal of Coatings Technology

J Electrochem Soc - Journal of the Electrochemistry Society

J Environ Qual - Journal of Environmental Quality

J Environ Hlth - Journal of Environmental Health

J Environ Sci - Journal of Environmental Science

J Exp Biol - Journal of Experimental Biology

J Gen Phys - Journal of General Physiology

J Hyg Epidem Microbiol Immun - Journal of Hygiene, Epidemiology, Microbiology and Immunology

J Inst Petrol - Journal of the Institute of Petroleum

J Macomol Sci Chem - Journal of Macromolecular Science, Chemistry

J Mar Biol Ass - Journal of the Marine Biology Association

J Mar Biol Ass U. K - Journal of the Marine Biology Association, United Kingdom

J Oil Colour Chem Asc - Journal of the Oil and Colour Chemistry Association

J Paint Technol - Journal of Paint Technology

J Protozoology - Journal of Protozoology

J Toxic Environ Hlth - Journal of Toxicology and Environmental Health

-K-

-L-

Labs - Laboratories

-M-

Mar Biol - Marine Biology
Mar Engng - Marine Engineering
Mar Pollut Bull - Marine Pollution Bulletin
Mar Technol - Marine Technology
Mar Technol Soc J - Marine Technology Society Journal
Mats Engng - Materials Engineering
Mat Ship - Materials and Shipping
Mats Perform - Materials Performance
Mats Prot - Materials Protection
Metal Finish - Metal Finishing
Metal Prog - Metal Progress
Mod Paint Coatings - Modern Paint and Coatings
MW - Molecular Weight

-N-

Nav Res Rev - Naval Research Review
NAVSEA - Naval Sea Systems Command
NAVSEA J - NAVSEA Journal
NAVSEC - Naval Ship Engineering Center (now NAVSEA)
NBS - U. S. National Bureau of Standards
NCEL - Naval Civil Engineering Laboratory
New Scient - New Scientist
Nippon Kokan Tech Rept Overseas - Nippon Kokan Technical Report Overseas
NOAA - National Oceanographic and Atmospheric Administration

NRL - Naval Research Laboratory

NTIS - National Technical Information Service

NSWC - Naval Surface Weapons Center

NUC - Naval Undersea Center

-O-

Ocean Engng - Ocean Engineering

Oceanology Intl - Oceanology International

Offshore Engng - Offshore Engineering

Oil Gas J - Oil and Gas Journal

ONR - Office of Naval Research

OTEC - Ocean Thermal Energy Conversion

-P-

Paint J - Paint Journal

Paint Manu - Paint Manufacturer

Paint Technol - Paint Technology

Pakist J. Zool - Pakistan Journal of Zoology

Postans Ltd - Postans Limited

Proc IEEE - Proceedings of the Institute of Electrical and Electronics Engineers

Prog Protozoology - Progress in Protozoology

Publ Amakusa Mar Biol Lab - Publication of the Amakusa Marine Biology Laboratory

Pwr Engr - Power Engineering

-Q-

-R-

Radiat Res - Radiation Research

Rubb Dev - Rubber Developments

-S-

Sea Technol - Sea Technology

Shipbldg Mar Engng Intl - Shipbuilding and Marine Engineering International

Shipbldg and Shipp Rec - Shipbuilding and Shipping Record

Shipp Wld - Shipping World

Shipp Wld Shipbldr - Shipping World and Shipbuilder

Sumitomo lt Metal Tech Rep - Sumitomo Light Metal Technical Report

-T-

Tanker Bulker Intl - Tanker and Bulker International

Tech Memo - Technical Memorandum

Tin Uses - Tin and its Uses

Toxic Appl Pharmac - Toxicology and Applied Pharmacology

Trans Am Soc Mech Engrs - Same as Trans ASME

Trans ASME - Transactions of the American Society of Mechanical Engineers

-U-

Undersea Technol - Undersea Technology

Underwat Sci Technol - Underwater Science and Technology

U.S.S.R. - United Soviet Socialists Republic (Russia)

-V-

-W-

Wat Air Soil Pollut - Water, Air and Soil Pollution

Wat Res - Water Research

Wat Serv - Water Services

Wat Sewage Wks - Water and Sewage Works

Wat Waste Engng - Water and Waste Engineering
Weld J (Miami, Fla) - Welding Journal (Miami, Fla)
Wood Preserv News - Wood Preserva+ News

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